SECRET
(When Filled In)

REVISED

R & D CATALOG FORM

DATE 19 August 1965

1. PROJECT TITLE/CODE NAME
Linear Phasolver Technique Study

2. SHORT PROJECT DESCRIPTION
A new concept in measuring techniques of an advanced design which accurately and rapidly converts minute linear translations into electrical (cont

3. CONTRACTOR NAME
25X1 [redacted]

4. LOCATION OF CONTRACTOR
[redacted] 25

5. CLASS OF CONTRACTOR
Manufacturer

6. TYPE OF CONTRACT
C.P.F.F.

7. FUNDS
25X1
FY 1965 $ [redacted]
FY 1966 $
FY 19 $

8. REQUISITION NO.

9. BUDGET PROJECT NO.
NP-MS-6

10. EFFECTIVE CONTRACT DATE *(Begin - end)*
1 Sept. 1965 - 30 Jan. 1966

11. SECURITY CLASS.
A.A. - Confidential
T. - Unclassified
W. - Unclassified

12. RESPONSIBLE DIRECTORATE/OFFICE/PROJECT OFFICER TELEPHONE EXTENSION
25X1 DDI/NPIC/P&DS/[redacted]

13. REQUIREMENT/AUTHORITY
This development is in direct response to a NPIC requirement for a large format, submicron, rapid translation, advanced state-of-the-art measurement capability.

14. TYPE OF WORK TO BE DONE
Applied Research/Engineering Development

15. CATEGORIES OF EFFORT

MAJOR CATEGORY	SUB-CATEGORIES
Measurement Techniques	Mensuration Systems
	Photogrammetry
	Electronics

16. END ITEM OR SERVICES FROM THIS CONTRACT/IMPROVEMENT OVER CURRENT SYSTEM, EQUIPMENT, ETC.
This is to be a modification of the Phase II phasolver test model to incorporate a coarse channel and associated circuitry to provide for display and print-out of encoded data, plus final testing.

17. SUPPORTING OR RELATED CONTRACTS *(Agency & Other)*/**COORDINATION**
There are no other known contracts of equivalent instrument design. Coordination has been conducted with other NPIC components and subsequent relevant mensuration programs.

18. DESCRIPTION OF INTELLIGENCE REQUIREMENT AND DETAILED TECHNICAL DESCRIPTION OF PROJECT *(Continue on additional page if required)*
The objective of this program is to provide NPIC with a measuring system that could be incorporated into present and future mensuration equipment designs. Present conventional techniques do not satisfy NPIC needs for sub-micron accuracy, extremely rapid and reliable measuring engines.

The original contract with [redacted] covering the period from June 1963 to June 1965, was for the development and demonstration of 2
(contd)

19. APPROVED BY AND DATE

OFFICE	DEPUTY DIRECTOR	DDCI
		Declassification Review by NGA

FORM 11-64 2338 SECRET GROUP 1 Excluded from automatic downgrading and declassification (1-13)

Continued...

2. phase-shift information.

18. a system capable of measuring linear movement with a resolution and accuracy of one micron or less.

Originally the linear phasolver was developed with a feasibility objective in mind and was quite successful in proving the validity of the basic concept. An extension and amendment of this contract with a change of scope to include a coarse channel and associated circuitry is required. The change of scope would provide for display and print out of the encoder data providing a demonstration of the feasibility of incorporating the linear phasolver into mensuration systems. Complete evaluation of the phase II phasolver is required, including performance and operation in relative humidities of 30, 50 and 70 percent.

The amendment to the present contract would extend the performance of the contract five months with an additional cost of

25X1 [redacted]

INTRODUCTION TO THE PHASOLVER*

The Phasolver is a precision device which converts very small mechanical movements into large electrical phase shifts. The output signal is phase modulated in direct proportion to the mechanical motion being measured. This analog phase shift can be displayed or subsequently digitized to represent the position of an antenna, cinetheodolite, star-tracker, or other device. The Phasolver principle is well suited to both rotary and linear applications and offers a number of advantages over other methods of measuring and reading out mechanical motion. Since the theory of operation is the same for both the rotary and linear applications, the discussion is limited to a rotary system.

A Phasolver system consists of two main units: the transducer or sensing device, and the associated electronics and digitizing equipment. (See Figure 1.)

The transducer is a highly accurate electrostatic phase shifter consisting of two non-conductive disks separated by a small air gap which allows significant capacitive coupling to occur. Upon one side of each disk a metallic pattern is vacuum deposited and the disks are mounted with the patterns facing each other. The pattern configuration is designed so that the area of the pattern varies sinusoidally with location on the disk. One disk, designated the "driver," forms one plate of a capacitor, is fixed to the reference structure and contains all electrical connections. The second disk, called the "coupler" is fixed to the rotating member and forms the second plate of the capacitor.

The electronics provide signals to drive the transducer and process the information out of the transducer into usable form. Input to the transducer consists of four sinusoidal signals of the same frequency, with equal amplitudes but having a quadrature phase relationship. Each signal drives a particular portion of the "driver" pattern. This energy is capacitively coupled to the "coupler" disk where the four signals are vectorially summed. The resultant is a single sinusoid with constant amplitude whose phase is directly proportional to the angular rotation of the "coupler" with respect to the "driver."

25X1 * Registered Trademark of [redacted]

PHASOLVER SIMPLIFIED SYSTEM DIAGRAM

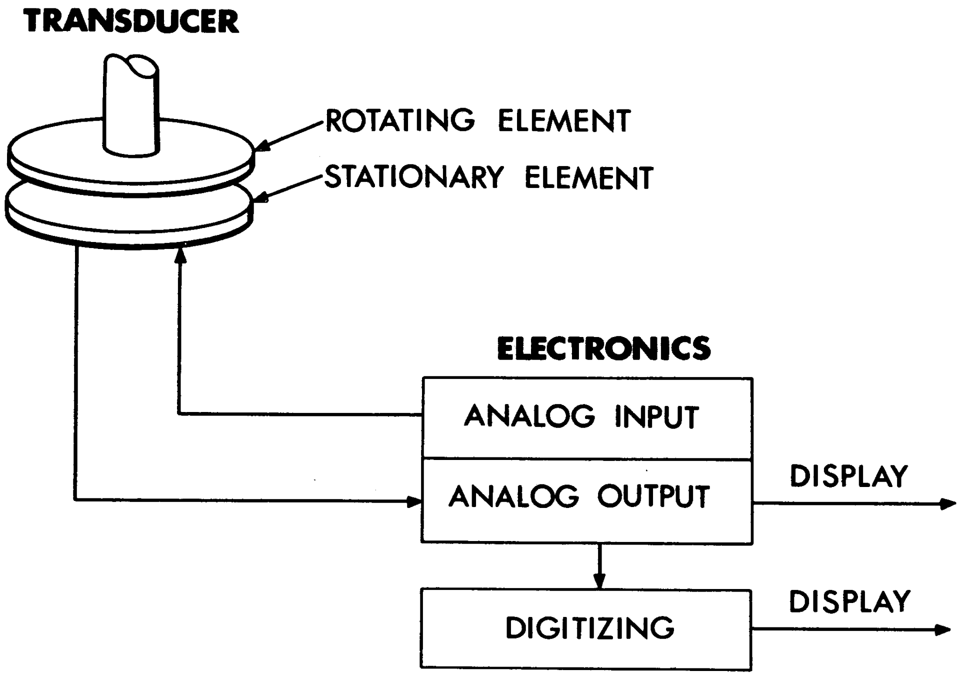

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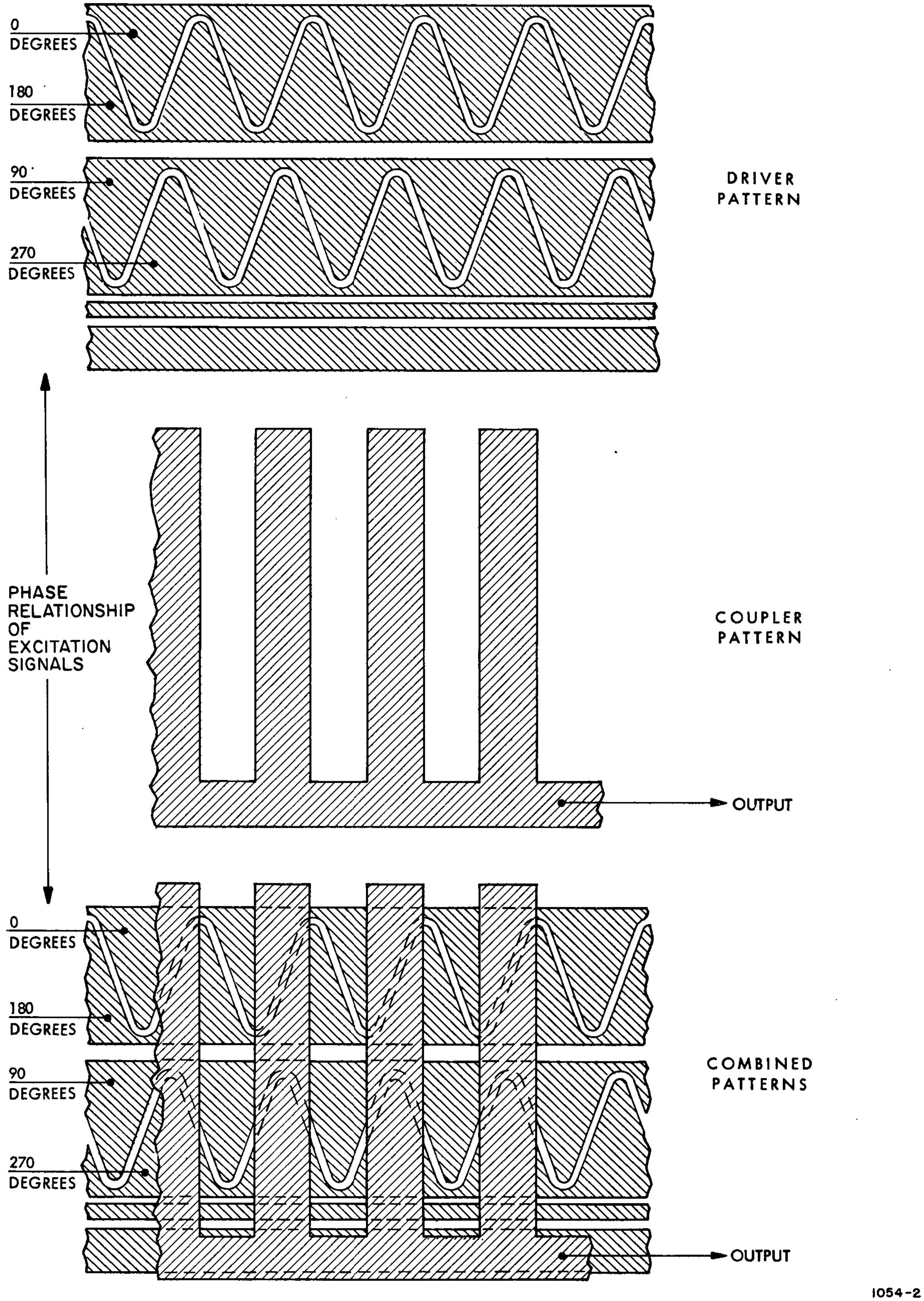
FIGURE 1

This constant amplitude, rotating phase vector is obtained as follows: The driver pattern consists of two sets of conjugate sinusoidal conductive areas which are physically displaced by 90°. (See Figure 2.) This pattern is excited by four AC signals of the same frequency and amplitude but having a quadrature phase relationship. The coupler pattern is made up of alternate conductive and nonconductive areas. (See Figure 2.) As the two disks move relative to each other, the first pair of conjugate sinusoidal areas on the driver disk induces a voltage into the corresponding rectangular area on the coupler disk. At the same time, the second sinusoidal pattern on the driver, which is physically phase displaced by 90° from the first pattern, induces a voltage into the same rectangular area on the coupler. As a result of the pattern geometry and the quadrature relationship of signal voltages, the voltages appearing on the coupler are $E \cos \theta$, $j E \sin \theta$, $-E \cos \theta$ and $-j E \sin \theta$.

When these are summed the resultant is a signal of constant amplitude and rotating phase. (See Figure 3.) The phase shift increases continuously from 0° to 360° as the coupler disk moves a distance equal to one sinusoidal cycle of the pattern. Because of the symmetry in arrangement of the pattern-pairs and coupler bars an average output of all pattern-pairs is obtained. This averaging effect results in minimizing errors introduced because of nonlinear pattern pair spacing or eccentricities in mounting of the disks.

The normal pattern configuration actually consists of two or three separate channels, each one operating as described above. Since the "fine" (high accuracy) pattern supplies an output waveform which repeats many times during rotation through a full circle, multiple channels are used to resolve any ambiguity and establish a unique output for each position. A simplified block diagram of a three channel system is attached as Figure 4.

Processing and digitizing consists of comparing, in real time, the phase shifted output signal with the input or reference signal. The reference signal starts a high speed clock and the pulses are counted until the phase shifted transducer output signal stops the count. At this point, the digital information in the counter represents the angular position of the system.



Phasolver Coupler and Driver Patterns

FIGURE 2

PHASOLVER PHASE SHIFT VECTOR ANALYSIS

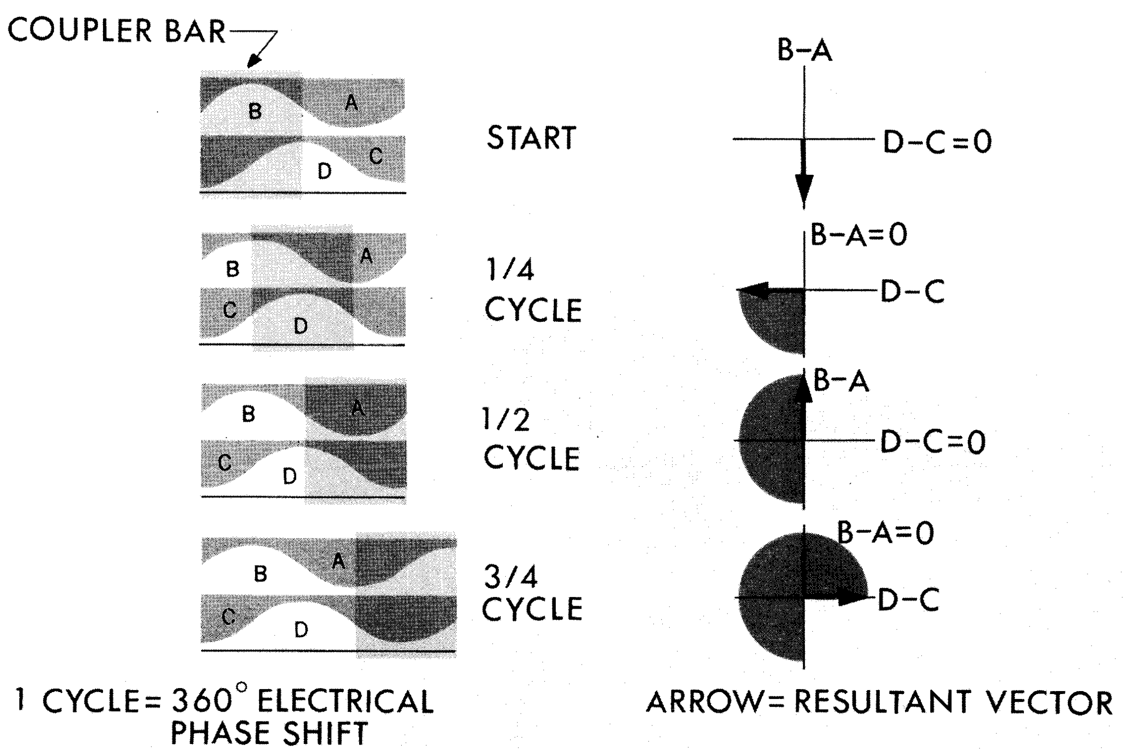


FIGURE 3

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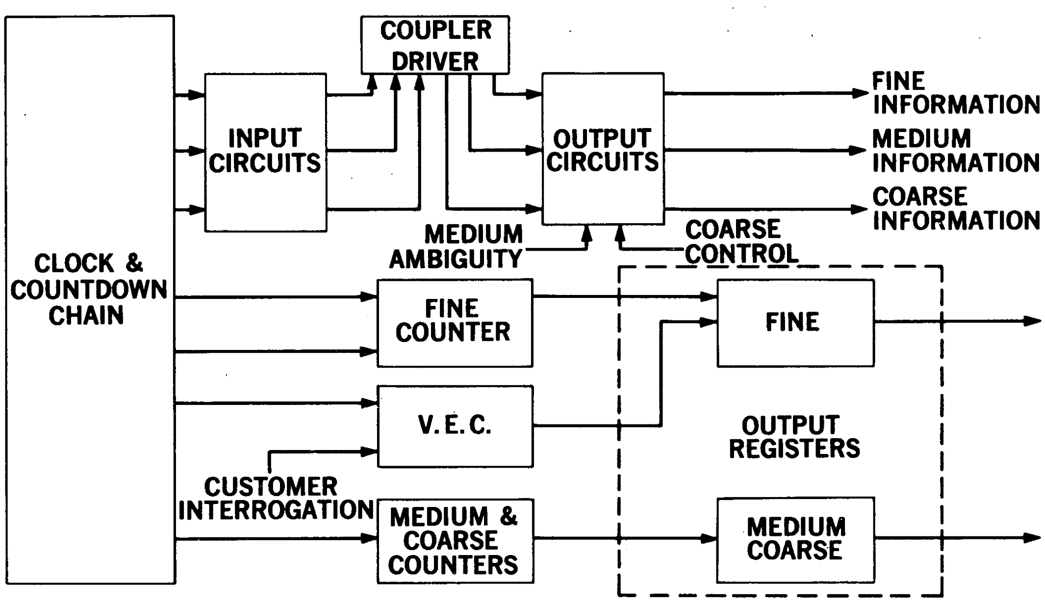

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Phasolver System - Simplified Block Diagram

FIGURE 4

PHASOLVER FEATURES

Extremely low power consumption.

All electronics are solid state.

Large range of transducer sizes, housings and mounting configurations.

Outputs can be analog, binary, BCD, decimal, etc., and are uniquely established; no accumulator techniques are used.

No electrical connections to moving elements.

No physical connection between moving and stationary elements.

No gears, lights, motors, or brushes.

The system is NASA qualified for satellite vehicles.

The system can be electronically zeroed in the field, allowing arbitrary zero reference selection.

Electrostatic coupling is not affected by ferrous metals or stray magnetic fields.

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SYSTEM CHARACTERISTICS

(Typical Rotational Encoder)

Resolution and Repeatability	1 arc-second
Accuracy*	±4.0 arc-seconds - <u>absolute</u>
Output Formats	Extremely flexible, including analog (phase-shifted pulses), binary, bcd, biquinary, decimal, etc.
Readout Rates	Updated absolute position information: 600 times per second
Velocity Effects	No accuracy degradation with velocities up to 60° per second
Physical Separation of Transducer and Electronics	Up to 1000 feet
Shock and Vibration Environment (Survival):	Shock: 30 g's for 6 and 11 milliseconds duration in each of three (3) mutually perpendicular axes. Vibration: 1) Sinusoidal 5-10 cps, 1/2" double amplitude 10-500 cps, 2.5 g zero to peak 400-2000 cps, 7.5 g zero to peak in each of three mutually perpendicular axes. 2) Random 15 to 2000 at 0.03 g^2/cps (Gaussian) in each of three (3) mutually perpendicular axes.

* All Phasolver systems are tested on an Ultradex Rotary Indexing Table accurate to 0.3 arc seconds. Systems with accuracies to ±1 arc-second are available for special programs.

ELECTRONIC PACKAGE CHARACTERISTICS:

Size	6" x 4" x 2" for a single-axis system.
Weight	From 8 oz. to 4 lbs. for a single-axis system in a flyable package. Exact weight depends upon accuracy and format requirements.
Power Requirements	Approximately 1 watt per axis
Environmental Temperature	Operational range: - 30° to +150° F.

TRANSDUCER CHARACTERISTICS:

Size	Available in any size from 4 to 30 inches in diameter, with or without center hole. The mechanical interface of the transducer takes on two optional forms. Option A: A complete encoder assembly including housing, bearings, coupling, etc. Option B: We can furnish the disks alone for integration into your mechanical structure providing the necessary instructions for mechanical mounting of the disks including specification of allowable gap variations, eccentricity, and parallelism of the transducer elements.
Weight	Approximately 6 oz. each for 4 inch O.D. disks.
Environmental Temperature	Operational range: -80° to +150° F.

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